Effect of Vibration and Noise on Spark Ignition Engines of Methanol Fuel Blended with Gasoline

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Nowadays, various types of engines are manufactured by the automotive industry, especially for cars that have huge demand all over the world in general, and Malaysia in particular. The vibration and noise continue to be a significant problem among the various issues that exist in the engine to date. In this research, tests were performed on a four-cylinder gasoline engine of methanol fuel blended with gasoline fuel at distinct quantities (between 5% and 10%) and motor speeds of 1000, 1200, and 1400 rpm. The findings indicate that the methanol gasoline combination has the highest vibration and noise between 1200 and 1400 rpm, while gasoline has the lowest vibration and noise between 1000 and 1400 rpm. The modifications in the combustion system owing to the characteristics of the fuel mixture used have an essential impact on the engine's vibration and noise.

Introduction

Biofuels can be used in different engines. Along with oil based fuels they include alcohol-based fuels like wood spirit and ethanol. Ethanol is produced from saccharose and starch by victimization chemical reaction through fermentation. The production of other biofuels involves a lot of issues such as use of corrosive chemicals, water demand, waste and pollution etc.[1–4] However, the use of alcohol fuels for transportation is a very good alternative and works best on spark-ignition engines (SI), it can mix well with fossil fuels.[5–7]

Out of various alcohols, production of wood spirit uses synthesis gas derived from biomass or alcohol with cheaper and acceptable energy prices.[8–10] Methanol production can even be possible through the employment of alkane.[11–13] In principle, methyl alcohol feedstock is mixed with gasoline up to fifteen volumes and may be used for combustion in SI engine with little or no modifications.

Many studies have employed the mixing of alcohol into petrol since the 1980s, and it is shown that mixed results between the transformation of fermentation alcohol and alcohol into gasoline are technically applicable and acceptable for SI combustion engines. Relative literature has explained numerous blends of ethanol, grain alcohol, and petrol fuels. The analysis on the result of a mix of petrol fuels with grain alcohol on the performance of spark ignition engines was done by Sakai *et al*.[14] Performance tests on the engine were done at different blending percentages of the fuel oil with fermentation alcohol at four-hundredth beneath conditions of variable compression quantitative relation.[15,16] The petrol mixed with grain alcohol shows increase torsion, brake power, fuel consumption, and volumetrically thermal potency, whereas the precise fuel consumption of the brakes and the fuel-air quantitative relation is reduced and equal as reported by Doğan *et al*. (2017) and Iodice *et al*. (2016).[(17,18)] Testing of grain alcohol fuel blends with fuel for conventional engines beneath various fuel water ratios (λ) equalizing emissions and engine performance have been reported by several authors.[19–21] The increasing fraction of wood alcohol mixed with the fuel will lower engine power and torsion once the throttle conditions are wide open (WOT).[22–24]

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Although the results of spark ignition and emission performance exploitation of alcohol-based fuels like (ethanol and methanol) have been conjointly investigated, studies on the effects of vibration characteristics on ignition engines moreover noise emissions exploitation of grain alcohol fuel and alcohol do not seem to widely be reported. The investigations created by different studies[25–28] on engine vibrations used different fuels like gas, kerosene, methanol, oil, and blends of wood spirit and fuel employing a smooth turbine shaft with the utilization of a free turbine driver measuring instrument. Vibration patterns were obtained throughout numerous operative conditions with the employment of a period time spectrum instrument. The oscillation movement was found at the time of multiplied combustion with the carbon-hydrogen quantitative relation of the fuel. As the load will increase, it mechanically decreases the frequency and primary harmonic amplitude. Therefore, the engine vibration level is foretold for fuel speed once the induction of combustion during a machine is on the far side style, the purpose of the look and medical specialty performed are helpful. The investigation of variations in idle diesel motor vibrations caused by entirely different fuel compositions has been performed, and the results showed a contribution to the difference in vibration on the handwheel.[29,30] To obtain the specific results of the vibration knowledge from the transient and periodic yields of the idle four-cylinder engine at totally different fuel conditions, it will use the technique of continuous-time moving ridge transformation (CWT) and time-changing variance (TV-AutoCov). Several studies[31–33] have investigated the consequences of liquified petroleum gas (LPG) and hydrocarbon for pressure and vibration throughout the combustion of spark-ignition engines. Increased vibration acceleration within the casting is because of excessive load and engine speed; the variation of fuel used is 22.1 to 100.5 m/s^2 and 4.1 to 95.5 m/s^2 for LPG operation. In such cases,[34–37] they are available on the relationship between the use of fuel-ethanol-oil intermixture with the vibration characteristics of spark ignition engines and conjointly for noise emissions. The experiments showed the amplitude of vibration, and sound emissions on the engine showed an inclination to extend significantly once exploitation mixed fuel for engine speeds of 1500 and 2500 rpm. The higher oxygen content, yet as higher heat than alcohol evaporation, has caused this result to extend. Thus,

pressure rate and pressure price are magnified once the height within the cylinder increase throughout the combustion method.

This study aims to analyze the results of vibration characteristics on SI engines response to petrol fuel mixed with wood spirit. Vibration measurements are carried out during the experimental process with different engine speeds. The examination was carried out to measure the characteristics of engine vibrations triggered by a mixture of methanol and gasoline, then compared before and after blend. The test uses 15% and 20% engine load with four speeds (1000, 1200, 1400, and 1600 rpm). This research is only to test the methanol-gasoline fuel mixture in two engine load conditions with different engine speeds. The methanol-gasoline fuel blend was applied because the previous research was still little done, especially for SI engine vibration measurements. The variables defined in this work are the latest in this article.

Experimental Setup

Experiments were conducted on pure gasoline and varied fuel blends of wood alcohol and ethanol, with different levels of various fuel blends between 5% and 10% respectively. Before the experiment, some fuel combination tests were determined by preventing fermentation alcohol reaction with vapor. The engine was initially heated for 20 to 30 minutes before being allowed to begin the experiment. Before the fresh fuel mix was loaded into the engine, the engine was left on for some moment to be able to consume the remaining fuel from previous tests. This experiment was performed with all fuel combinations prepared with distinct load circumstances and engine speeds. This experiment was performed until the maximum rotation was achieved, in particular by beginning the speeds of 1000, 1200, 1400, and 1600 rpm. The dynamometer controls the required engine load is acquired.

There is a wide variety of characteristics in the engine in response to combustion of each fuel. The fuel's properties can change engine efficiency, vibration, and emission features. Considering the fuel properties associated with the burning, each fuel was evaluated in the laboratory using conventional ASTM tests. Fuel characteristics were determined for various combinations of methanol and ethanol fuels, as shown in Table 1.

The experiments carried out in the study were carried out eight times. Experimental tests were

applied to engine loads of 15% and 20%. In the first experiment, it was tested with an engine load of 15% for each engine speed (1000 rpm, 1200 rpm, 1400 rpm, and 1600 rpm). Furthermore, the second test was applied to the engine load of 20% for the same engine speed.

This research utilizes some of the required instruments such as motors, vibration analytics instruments, and dynamometers as shown in Fig. 1, the schematic diagram setup experimentally. The requirements of the four-cylinder engine used in this research are shown in Table 2. The engine used in

studies is Mitsubishi 4G93 SOHC type, four-cylinder fuel injection, maximum power of 86 kW, maximum torque of 161 mm bore stroke of 81.0 mm × 89.0 mm. An elastic coupling connects a dynamometer device to a machine. This dynamometer is used for monitoring and measuring torque, as well as an instrument panel fitted for remote control of load or engine velocity.

The mechanical vibrations obtained from the engine cylinder block were evaluated using the domestic instruments (NI), as shown in Fig. 1 and Fig. 2, at the moment of engine operation utilizing the combination

Table 1 — Properties of various fuels[38]

Property	Lower heating value (MJ/kg)	Kinematic Viscosity, 40°C (mm^2/s (cSt)	Research octane number	Density, 15.5 ºC (kg/l)
Gasoline	44.106	0.55	95	0.748
Methanol	(M5) 0.7688 (M10) 0.7702	(M5) 0.5269 (M10) 0.5286	(M5) 91.3 (M10) 88.2	(M5) 0.8222 (M10) 0.8466
Test Method	ASTM D340	ASTM D445	ASTM D2699	ASTM D455

Fuel properties		Gasoline	Methanol
Density @ 20 °C (g/cm^3)		0.745	0.796
Kinematic viscosity (mm^2/s at 40 °C)		0.494	0.596
Oxygen content (% wt.)		< 0.05	50
Research octane number		95	108.7
Stoichiometric air/fuel ratio		14.7	6.49
Viscosity @40 °C (mm^2/s)		0.4–0.8	0.59
Surface tension @ 27 °C (10^{-3} N/m)		18.93	22.18
Latent heat of vaporization @ 25 °C (kJ/kg)		305	1103

1. Fuel Filter
2. Fuel Pump
3. Transducer pressure
4. Drain Value
5. Encoder Crank
6. Sensor
7. Data acquisition system for noise and vibration
8. Engine Data
9. Cylinder 1
10. Cylinder 2
11. Cylinder 3
12. Cylinder 4
13. In-Cylinder pressure transducer
14. Fuel Tank
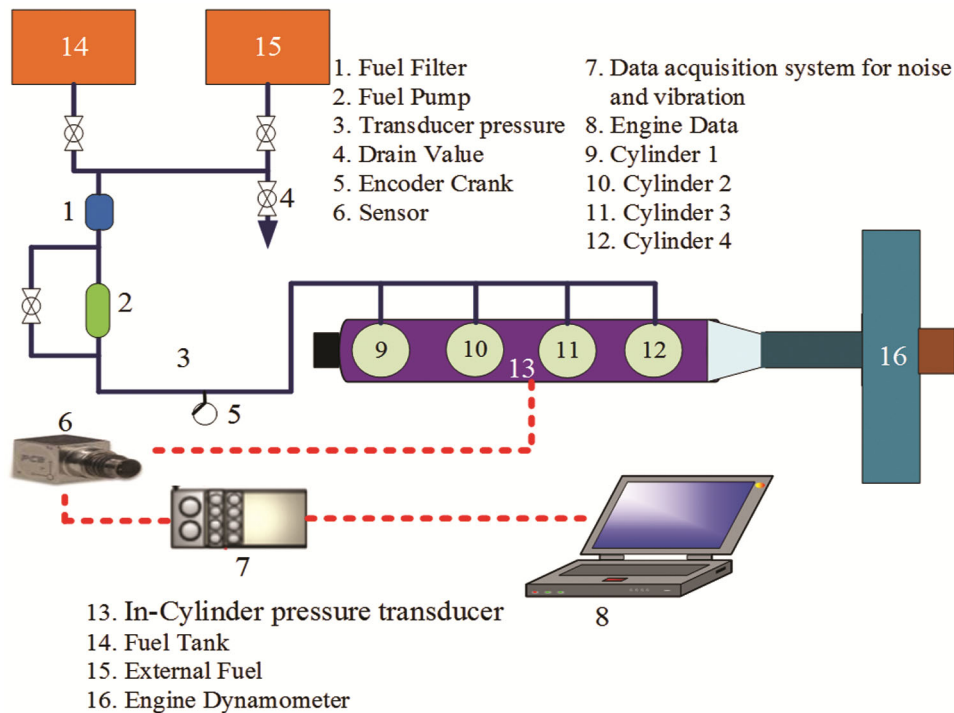15. External Fuel
16. Engine Dynamometer

Fig. 1 — Schematic engine setup

of the mixed gas with the alcohol-based fuel. This accelerometer was positioned on the motor surface adjacent to the head of the car. Besides, the signal from the captured voltage accelerometer was registered in a computer linked to the accelerometer: the sound and vibration analysis were performed with the assistance of 'ME'ScopeVES software. Control was carried out

Table 2 — Specifications of engine

Engine Specifications	
Engine type	Mitsubishi 4G93 SOHC
Bore stroke	81.0 mm × 89.0 mm
Number of cylinders	4 (1st cylinder is instrumented)
Fuel injection type	MCI-Multi (Electronically Controlled Multi-pint) fuel injection
Piston displacement	1.834 L
CR	9.5:1
Max power	86 kw @ 5500 rpm
Max torque	161 nm @ 4500 rpm

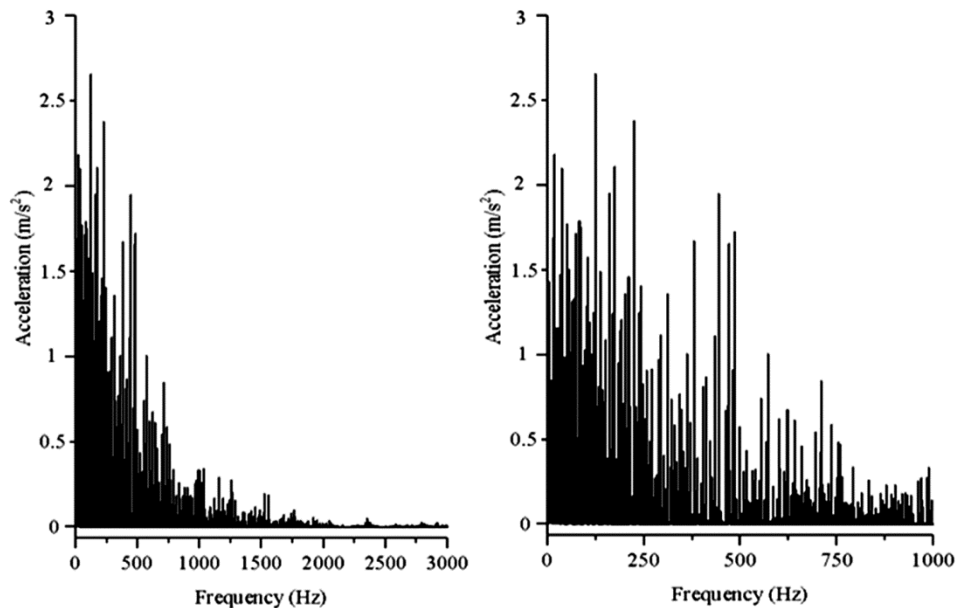Fig. 2 — NI acoustic and vibration data logger and cable uni-axial

while the experiment was in progress. All information samples were registered depending on the velocity and fuel used to make the evaluation simpler.

Results and Discussion

Unit of internal combustion engine vibration signals manages PC communication, while accelerometer measurements are standard multi-harmonic signals localized in short time intervals and spread over the cycle duration. Structures cause the frequency cycle during engine combustion and non-harmonic constant frequency response at natural frequencies that have a relationship between frequency harmonic answers integrally to machine structure.[39] The spectrum on the Z-axis shows 0–3000 Hz, and 0–1000 Hz is the vibration from the surface at a certain point when the engine was triggered by a blend of methanol-gasoline fuel at maximum load with a speed of 1000 rpm, as shown in Fig. 3. The spectrum was plotted into a scale linear frequency and not planned in the form of a frequency logarithm function. Thus, the most prominent component was at 153 Hz and 160 Hz. Another exciting spectrum measurement result for the spectrum in Fig. 4 is that the center of the highest level was significantly recorded as 68.21 Hz, the middle peak was 424.4 Hz, and the height peak was 804.4 Hz. The results above are the peak of the harmonic indication of the cycle frequency

The experimental results analyzed the frequency of the Z-axis because analysis of results for the X, Y,

Fig. 3 — Acceleration spectrum Z-axis for the engine using fuel blend, at 1000 rpm

and Z axes has shown similar features. The spectrum of frequencies along the Z-axis when the machine operated at different speeds for 15% engine load using mixed methanol-gasoline fuel is shown in Figs 4 & 5. Significantly, the engine frequency
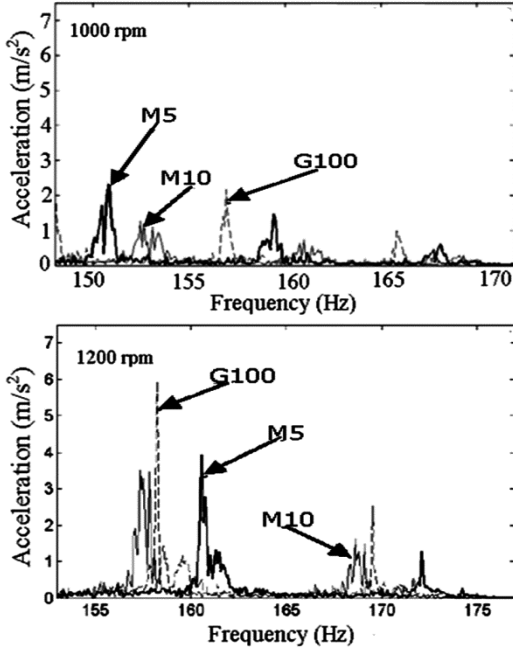

Fig. 4 — Frequency spectra Z-axis for the engine using fuel blends (M5, M10, and Gasoline) at speed 1000 rpm, 1200 rpm, and load 15%
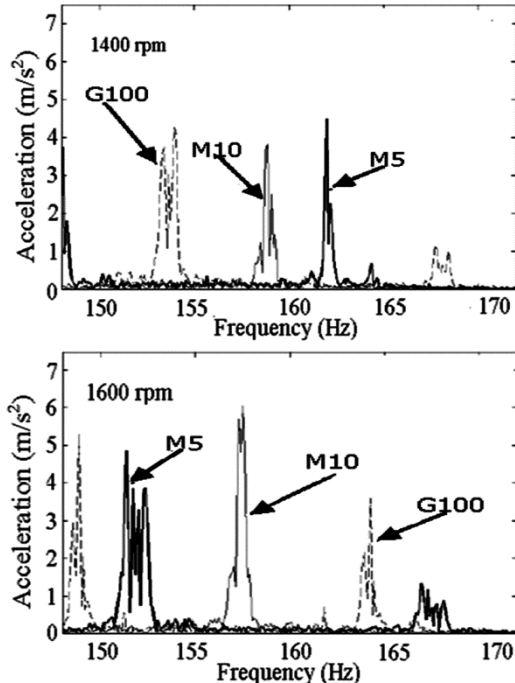

Fig. 5 — Frequency spectra Z-axis for the engine using fuel blends (M5, M10, and Gasoline) at speed 1400 rpm, 1600 rpm, and load 15%

spectrum changed between 153–177 Hz for the entire sample of fuel testing. In general, increasing engine speed shows a reduction in the amplitude of harmonic vibrations, especially for mixed fuels. The highest magnitude of vibration was 4.729 m/s^2 (158.3 Hz) at 1200 rpm when the engine operated with gasoline. However, the M10 combination was recorded to produce the highest vibration at 6.066 m/s^2 (162.5 Hz) at 1400 rpm compared to gasoline and M5, while the gasoline-methanol combination (G95%-5%) provided a more stable amplitude level of (3.933 m/s^2 160.6 Hz, 4.482 m/s^2, 167 Hz and 4.863 m/s^2 156.4 Hz) at 1400 and 1600 rpm.

The spectral frequency on the Z-axis is presented as the second case study in this study, where the operation of the engine used a combination of gasoline-methanol with volume ratios (M5 and M10) compared to pure gasoline at 20% engine load and different speeds, as shown in Figs 6 & 7. Engine vibration characteristics show an increasing trend in mixed fuels used compared to pure gasoline. The M5 fuel combination acceleration level was lower. The tested combined fuel showed the vibration characteristics of the engine at a speed of 1000 rpm with a load of 20%, having an amplitude value between 151 and 156 Hz. The maximum vibration when the engine was triggered by pure gasoline was about 5.754 m/s^2 (156.3 Hz) measured at 1200 rpm,
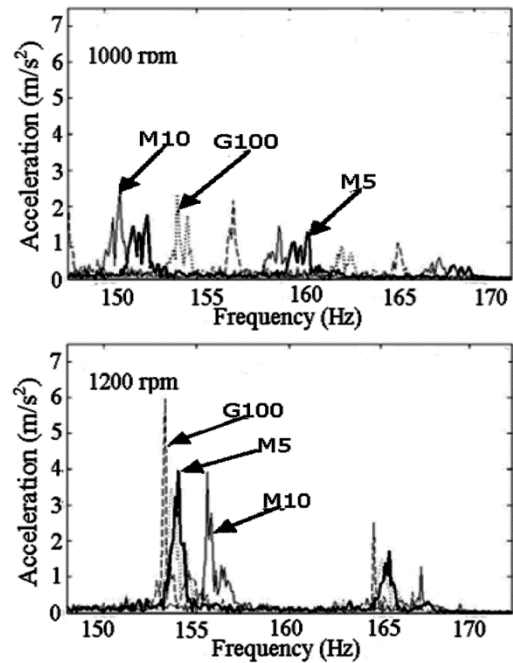

Fig. 6 — Frequency spectra Z-axis for the engine using fuel blends (M5, M10, and Gasoline) at speed 1000 rpm, 1200 rpm, and load 20%
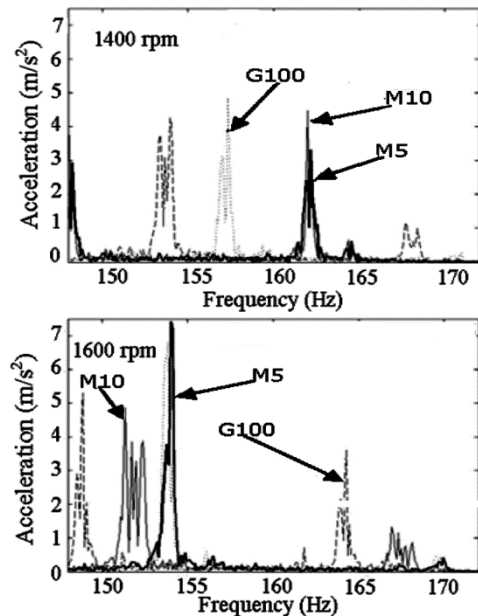
Fig. 7 — Frequency spectra Z-axis for the engine using fuel blends (M5, M10, and Gasoline) at speed 1400 rpm, 1600 rpm, and load 20%

while the M10 fuel combination produced significantly lower values of 3.733 m/s^2 (156 Hz), 3.784 m/s^2 (157 Hz), and 3.431 m/s^2 (156.7 Hz). Tests carried out at a speed of 1600 rpm for 20% engine load showed almost the same vibration level of 156.9–165.2 Hz. Besides, observations made for engine vibration characteristics of mixed fuel M5 and M10 showed amplitude values with the highest acceleration between 7.21 m/s^2 (157 Hz) and 6.705 m/s^2 (156.8 Hz) at 1600 rpm. Therefore, the M5 combination produced vibrations higher than gasoline and increased further compared to the M10 mixture.

The experimental results on the spark ignition engine operated using pure gasoline fuel with a combination of methanol (Methanol 5% and Methanol 10%) showed changes in vibration in the engine. This change is caused by changes in the engine combustion process from the fuel used. Similar research results from several previous studies have also been reported.[40] However, this test was done on different engines and fuels.

Conclusions

The results of the tests showed that the engine triggered by the methanol-gasoline mixture changed significantly by 148–173 Hz. Increased engine speed can reduce the necessary harmonic amplitude acceleration. The peak of engine vibration using gasoline was in a narrow band around 150–155.3 Hz.

The methanol-gasoline combination tested showed the most stable vibration acceleration level. The introduction of mixed fuels to measure engine vibration spectra can apply at engine speeds of 1600 rpm. The changes in the combustion process of the machine can explain the results caused by the properties of mixed fuels. These results can be used as a comparison for future work in measuring vibration waves using the process against vibration signals.

Acknowledgments

Nomenclature

RPM	Revolutions per minute
λ	Lambda
SI	Spark-ignition
LPG	Liquified petroleum gas
MJ/kg	Megajoules per kilogram
kW	Kilowatt
ASTM	American society for testing and materials
M5	Methanol 5%
M10	Methanol 10%
ºC	Degree celsius
Hz	Frequency

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